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Development of General Creativity and Mathematical Creativity by MCR Pedagogy

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ABSTRACT

Research regarding creativity has been gaining momentum during the last century. At first, creativity was perceived as a form of ingenuity, an innate talent that could not be developed. Research of the 1960's started showing that creativity can in fact be developed, but the focus was in the characteristics of creativity and did not examine the means of its development. During the 1990's, research about creativity in education has been flourishing. (Lev-Zamir, 2004)

There is not a single, official definition for creativity (Mann, 2006; Sriraman, 2005). There is a wide spectrum of perceptions and opinions about the essence of creativity that changes from time to time. Through the vast range of different and diverse definitions, one can assume that creativity is a complex phenomenon that carries many dimensions which create different definitions.

Many sets of trials measure creativity. Torrance (Torrance, 1974) has tried to create situations that represent the creative process, and their grading is based upon the four features of creativity that Guilford (Guilford, 1971) has suggested: Fluency, Flexibility, Originality and Elaboration. Fluency is the number of answers or ideas that were registered in a limited time frame. Flexibility is the number of categories, departments, of the answers or the ideas registered. Originality is the extent of rareness of the idea. Elaboration refers to the ability to describe, shed light upon, and combine ideas.

Many researchers express the importance of teaching mathematics in a method that encourages creativity among pupils. (Lev-Zamir ,2014). Mevarech (2016), suggested that mathematical problems that have the potential to develop hold the following characteristics: complex, unfamiliar and non-routine. In short: CUN.

Bruch (Bruch, 1988) mentioned the term meta-creativity in the past. Explaining its meaning, meta-creativity means the awareness of thoughts and feelings during creative experiences. That is to say, meta-creativity is conducting internal observance over creative processes and personal features that create a new idea. Bruch expressed the importance of meta- creativity, stressing that creative imagination has more significance than knowledge learned from textbooks.

Mevarech (2016) developed MCR (meta-creativity) pedagogy, to improve meta-creativity on the classroom: according to this method, the acronym CREATE forms a frame for the basic phases of creativity improvement: **C**ore problems and sub-

problems, **R**econstruct connections to generate ideas, **E**xplaining and **E**xperimenting, **A**dditional strategies/ methods / technologies, **T**rue – but, **E**valuation.

In order to implement the method successfully, four principles are needed:

1. Explicit fulfilment of the MCR process: applied meta-creativity problems, in which the students are required to solve upon facing different questions. The questions in the research were compiled according to the CREATE principals, yet did not include all the aspects of CREATE: a) deconstruct the problem to its components: which information you think is needed to solve the problem? b) if you had the information you wrote, how would you use it to solve the problem? c) is the solution reasonable? Or alternatively – do you feel stuck? Why? d) is there another way to solve the problem? Find as many solutions/ways possible!

2. Implementation of MCR in the syllabus: exposure to the subjects that use MCR while studying. Such as "CUN assignments".

3. Informing the students about the benefits of MCR and encourage them to invest the initial first effort.

4. Consistent training, in order to assure a thorough implementation of the MCR principles.

CREATE is based on a meta cognitive (MC) paradigm, called IMPROVE, developed by Mevarech and Kramarski (2014). Over the IMPROVE method many researches were made, indicating the great positive effect of the method over scientific-mathematical thought.

In this current research we have tried to examine if the MCR pedagogy develops general creativity and mathematical creativity, among students in 9th-10th grade. For the purpose of this research, a tool was developed to examine mathematical creativity based on the TTCT tests, and it was adjusted to the mathematical field. We tried to answer the following questions: 1. Is the research tool for examining the mathematical creativity valid? 2. What is the effect of the MCR pedagogy over the general creativity among students in 9th-10th grade, and over each of its components: Fluency, Flexibility, Originality and Elaboration? 3. What is the effect of the MCR pedagogy over the mathematical creativity among students in 9th-10th grade, and over each of its components: Fluency, Flexibility, Originality and Elaboration?

110 students participated in the research, 94 (85.5%) girls and 16 (14.5%) boys, who study in the 9th grade (63.6%, n=70) and the 10th grade (36.4%, n=40). Most of the participants' fathers (69.1%, n=76) and most of the mothers (86.4%, n=95) are of

academic education. The participants studied in different levels of mathematics. Most of them studied in the 5-units level (62.7%, n=69) some in 4-unit level (24.5%, n=27) and the minority are 3-unit level (12.7%, n=14).

In this research we will be using five tools: tests to examine general creativity (Torrence, 1974), tests of mathematical creativity, demographic data, questionnaire on creativity and mathematics and finally a feedback questionnaire concerning the contribution of the intervention.

To check the research assumptions, the participants were divided into two groups: intervention group and a comparison group. The comparison group consisted 54 students. The intervention group was asked to undergo a preparatory test, the intervention and a post-stage test. The preparatory test included a test of general creativity (attachment no,1), mathematical creativity test (attachment no.3), demographic data (attachment no.9), and questionnaire on creativity and mathematics (attachment no.10). During the intervention, which lasted four weeks long, the students were asked to answer four tests, one per week about mathematical creativity (attachments 5-8). The tests were presented online and incorporated guidance for solving the problem based on MCR pedagogy: the students were asked to find a solution while using meta-cognitive questions. The post stage test included a test for general creativity (attachment 2), mathematical creativity test (attachment 4) and feedback questionnaire concerning the contribution of the intervention (attachment 11).

The comparison group had 56 students. they were instructed to participate in the preparatory test and a post stage test. The preparatory test was identical to the test provided to the intervention group. The post stage test given to the comparison included a general creativity test (attachment 2), mathematical creativity test (attachment 4) and did not include feedback questionnaire concerning the contribution of the intervention. There was no significant dependence or significant differences between the background variables and the study groups, so there was no need to monitor the background variables in the hypothesis test.

In the framework of the examination of the first research question, a very similar pattern was found of the relationship between the averages of the various creativity measurements, between the research tools developed (the test of mathematical creativity), and the test of different uses for an object (TTCT), developed by Torance. Conclusions can be drawn about external (convergent) validity, and the validity of the type of the tool developed. In addition, a correlation was found between

the score of the participants in most of the creativity measurements and their self-definition for their level of creativity. In addition, high percentages of agreement were found among the judges, as well as positive, significant and intermediate correlations between the scores in the re-test, similar to the findings on the test of creativity.

As part of the examination of the second research question, in order to examine the effectiveness of the intervention program in improving creative ability and in light of the differences between the research groups in the preliminary stage, a series of one-way differences analysis was conducted MANCOVA one-way and ANCOVA one-way while monitoring the preliminary stage scores. In the test of different uses for an object (TTCT) Significant differences were found between the research groups in the general index of creativity, as well as Fluency, Flexibility and Originality. According to the standardized averages, there was a decline in the level of creativity in both groups, but in the comparison group the decline was greater. In the improvement index there was no significant difference between the groups. In addition, the participants' scores were related in between the majority of the creativity measurements (general creativity, Fluency and Originality, and one of the questions also the flexibility index), and between their benefit from two accompanying questions that the participants were assisted during the intervention.

As part of the examination of the third research question, in order to examine the effectiveness of the intervention program in improving creative mathematical ability and in light of the differences between the research groups in the preliminary stage, a series of one-way differences analysis was conducted MANCOVA one-way and ANCOVA one-way while monitoring the preliminary stage scores. In all the measurements of creativity for the mathematical creativity test no significant differences were found between the research groups in the post-stage test, while monitoring the preliminary stage scores. However, a correlation was found between the participants' scores in all of the creativity measurements (beside the elaboration measurement) and between their benefit from two accompanying questions that the participants were assisted with during the intervention.

The two questions that the participants testified as helping them answer more creatively were questions that they were asked to answer after some experience with the problem. The two questions that were found to have not contributed to creativity related to preparing to answer the problem. Naturally, after trying to solve the problem,

it is easier to report on the solution process. On the other hand, it is more difficult to answer questions that precede experimenting with the problem.

In examining the distribution of the findings before the background data, it was found that there are significant differences between boys and girls in some of the creativity measurements (general creativity, fluency, flexibility) in the test of mathematical creativity, as well as differences between 9th grade students and 10th graders, in some of the measurements (general creativity ,flexibility and originality) in the test of general creativity. No other differences were found in the other demographic data examined.

The study found that there was a significant correlation between the three measures of creativity: Fluency, Flexibility and Originality. Elaboration, as compared to the other measurements, were found to be less related to them. It is possible that a participant presented only one reference, but very detailed it, and received a very high score for Elaboration, compared to another participant, who wrote a lot of references without detail. Indeed, in the original test Torance mentioned that the Elaboration measurement is possible to examine mainly in the drawing test, and not in the verbal test (Nevo, 1997).

In addition, it was found that at the beginning of the research creativity, both general and mathematical, were very high in relation to the continuation of the study. It can be said that during the data collection process and at the beginning of the study, participants were given a sense of belonging and personal connection, a sense of ability and autonomy. All of these created a high internal motivation among the participants, which helped them to be more creative. In the continuation of the study, internal motivation decreased due to the decline in its components; therefore, creativity also decreased in general, relative to the level of initial creativity.

In addition, the changes in the level of creativity can be explained by the fact that in the process of analyzing the responses to the various questionnaires of the intervention, it was possible to see that each of the mathematical problems presented in the test of mathematical creativity demanded different creative abilities. It can be said that to examine the effectiveness of MCR pedagogy in the development of mathematical creative thinking, two major changes are required: changing the mathematical problems to those that are appropriate to test creativity and encouraging in students the same skills. Changing the first two accompanying questions.

During the course of the study, many boys dropped out compared with the girls. It is possible that the structure of the problems, which required verbal answers, caused the boys to drop out and for the girls to stay (TIMES, 1999).
In this study there was no competitive atmosphere, and the lack of competitiveness could have caused the boys to drop out as well (Mevarch & Libberman, 2001).

In addition, it was found that 10th graders received grades higher than ninth graders on the test of general creativity, accordingly to Guilford's curves (Guilford, 1972) and Gardner (Gardner, 1995), that describe the increase of creativity level in their teens.

Limitations of the study are: the number of students participating is not great, the results may be different if we share students of other ages. The duration of the intervention period is not long, and the intervention is online and not at formal class setting in the schools. A sample that contains boys and girls equally may yield different results.

It is recommended to conduct follow-up studies in which there is a group that answers all the problems, including those of the intervention, but without the accompanying questions.
Studies that will examine intervention in class rather than on an internet forum.
Examine different ages, add background variables, and use valid mathematical tasks.